

Proton Plan
MI Radiation Issues and Collimation
Accelerator Division Review
July 2005

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Topics to Be Discussed:

- MI Radiation Levels and Trends
- MI Radiation Monitoring Program
 - Residual Radiation and Monitoring Automation
 - Loss Monitor Status and Upgrades
- MI Collimation Prospects and Plans
 - Loss Issues
 - Lattice Overview
 - Loss Study and Simulation Plans
- MI8 Collimation
 - Specification
 - Design and Implementation Plans
- Risk Assessment, Schedule, Costs

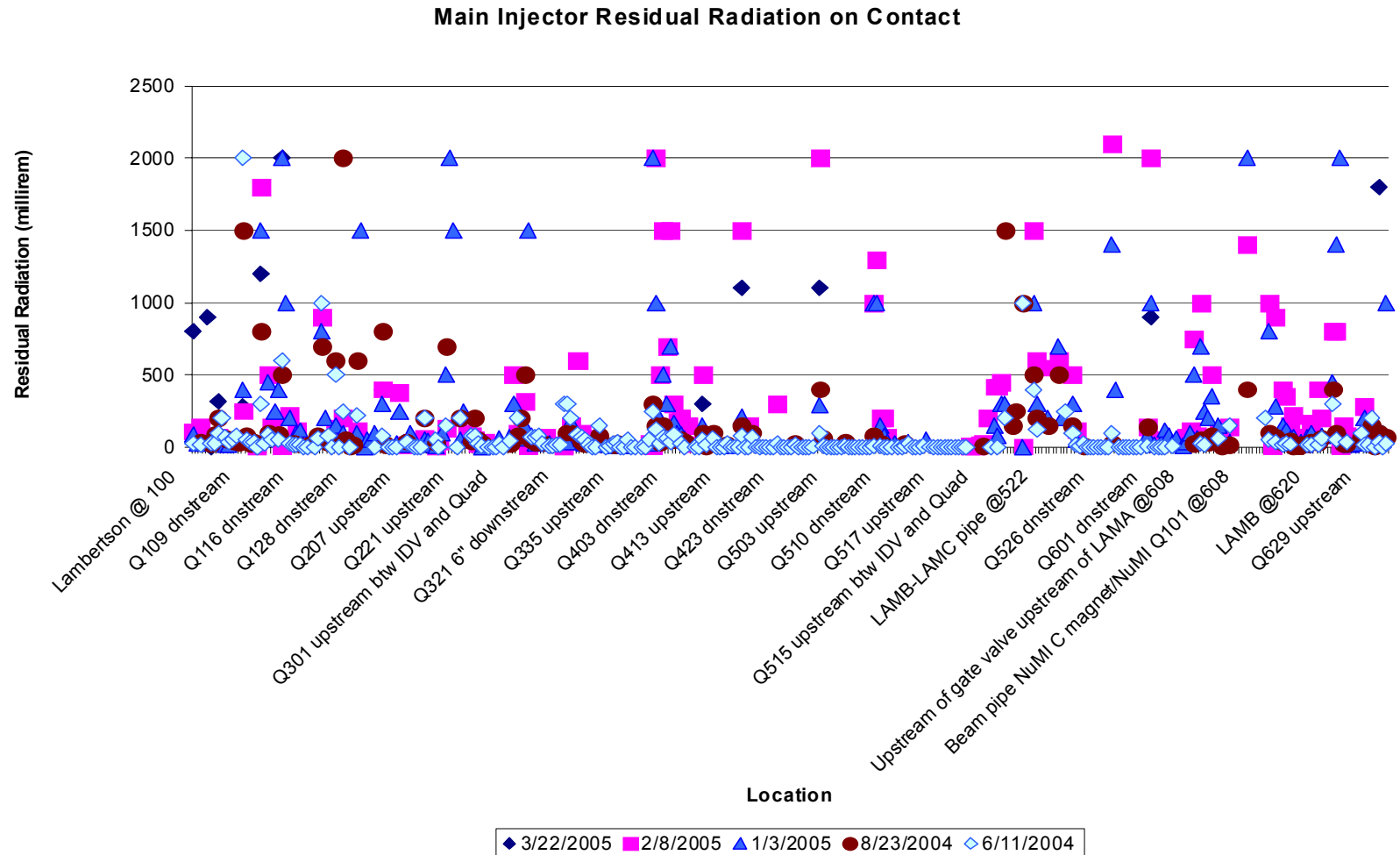
- The Main Injector was sited at a depth which provides adequate shielding so **environmental issues do not normally arise**.
 - Exception: MI Abort is authorized for limited use.
- However, all components are designed for hands-on maintenance. **Residual radiation must be kept to levels which permit maintenance**.
 - We interpret this to mean less than 100 mr at 1 foot.
 - Unlike the Booster RF, there are no MI components (rf, instrumentation) which are predicted to need maintenance and have radiation-inducing aperture limitations. **Where will residual radiation define limits?**
- Radiation damage to components may be a separate issue. We expect to operate the machine such that the residual radiation will be

limiting. [Do not dump beam in magnets!]

Tunnel Residual Radiation Monitoring:

- **Diagnostic Measurements** - all sides of beam pipe at locations which show significant radiation
 - Carried out in June-August 2004 and as possible in 2005
 - Few mr exposure per survey in 2004, 20-30 mr in 2005
 - 2005 surveys incomplete (limited by time and exposure)
 - Comparison of top vs. bottom or inside vs. outside diagnostic of machine problems
- **Monitoring** - periodic measurements at 'significant' locations around MI Ring.
 - Manually with LSM through July 2005
 - **Bar codes plus logging meter system being implemented - monitor about 125 points**
 - Database and data transfer efforts still needed
- Robot would be helpful - more complete, less exposure.

Residual Radiation measurement have been recorded and reviewed.

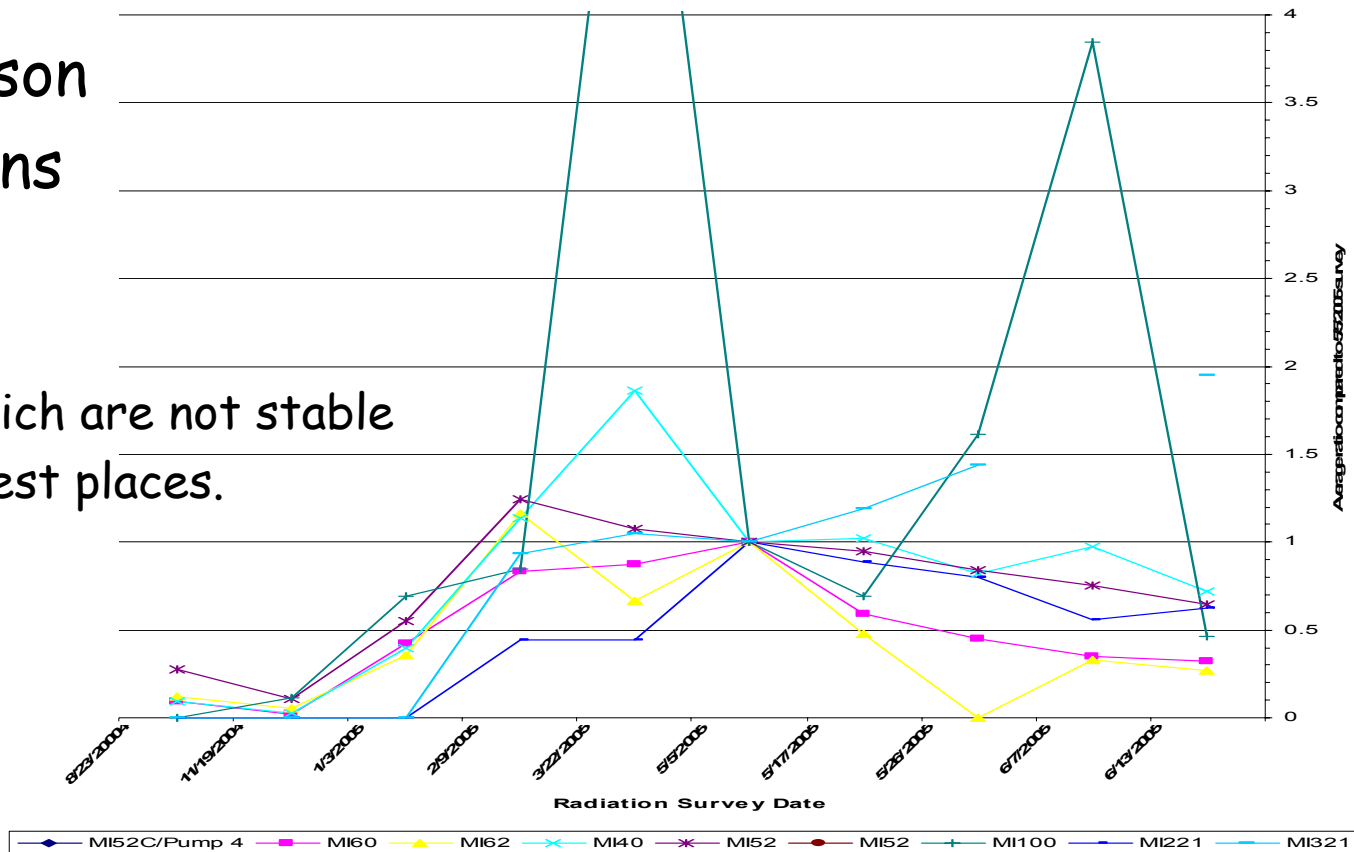


Radiation trends have been monitored at locations with significant radiation

History of Lambertson Residual Radiation

Lambertson Locations

Locations which are not stable are not hottest places.



Issues noted:

- Vertical problem at D-Quad Minitubes (tails)
- Radial Problem at F-Quad downstream (longitudinal)
- Lambertsons
- Blunders (alignment, BPM errors)

We must limit the number of hot locations if we hope to understand existing or new loss sources.

MI Loss Monitors

- Adequate number of Tevatron-style Loss Monitors
- Old Electronics is not adequate
 - Cannot report integrated losses but from a few locations. It is adequate for many studies but not suitable for most long term monitoring needs.
- New electronics is being developed which will provide much better real time and logging capability. It should be available in FY06.

Expect to predict residual radiation based on losses (As in Booster). If some losses are not seen by existing LM's we can supplement them with coaxial 'Total Loss Monitors' for some areas.

What do we know about Main Injector Losses?

- Losses at Injection
- 8 GeV Lifetime
- Slip-stacking Losses - beam lost from design buckets
 - Recaptured in undesired buckets (lost at inj or ext)
 - Uncaptured beam (DC Beam lost on acceleration)
- Losses at MI Transition
- Losses during extraction/transfer

Each of these loss sources has a distinctive pattern for creating residual radiation

The Main Injector Lattice has no collimation locations in the design. Features include:

- Regular Cells
 - Only Mini-straight sections
 - Moderate dispersion
- Dispersion suppressor cells
 - No straight section space
- Straight section cells
 - Design dispersion is zero
 - All have dedicated use - transfer, instrumentation, rf

MI Collimation Possibilities

Straight section uses:

- MI52, MI62 Transfer to Tevatron - radial
- MI40 Abort - radial
- MI 10 Injection - vertical plus instrumentation
- MI60 RF, Instr, NuMI Transfer - radial
- MI22, MI32 Radial Transfer to RR
- MI30 Mostly used for electron cooling

Currently we are considering creating some vertical collimation at MI22 or MI32 and radial at MI30

No location with dispersion has been identified.

MI Loss and Collimation Study

Nikolai Mokhov and colleagues will carry out a study of apertures and loss mechanisms in the Main Injector with the goal of prescribing a suitable set of collimators to localize beam lost due to various identified mechanisms

We speculate that significant lattice modifications will be required to create a section with dispersion where collimation can be placed if we wish to remove unaccelerated beam with collimation.

MI8 Collimation Plan

Purpose:

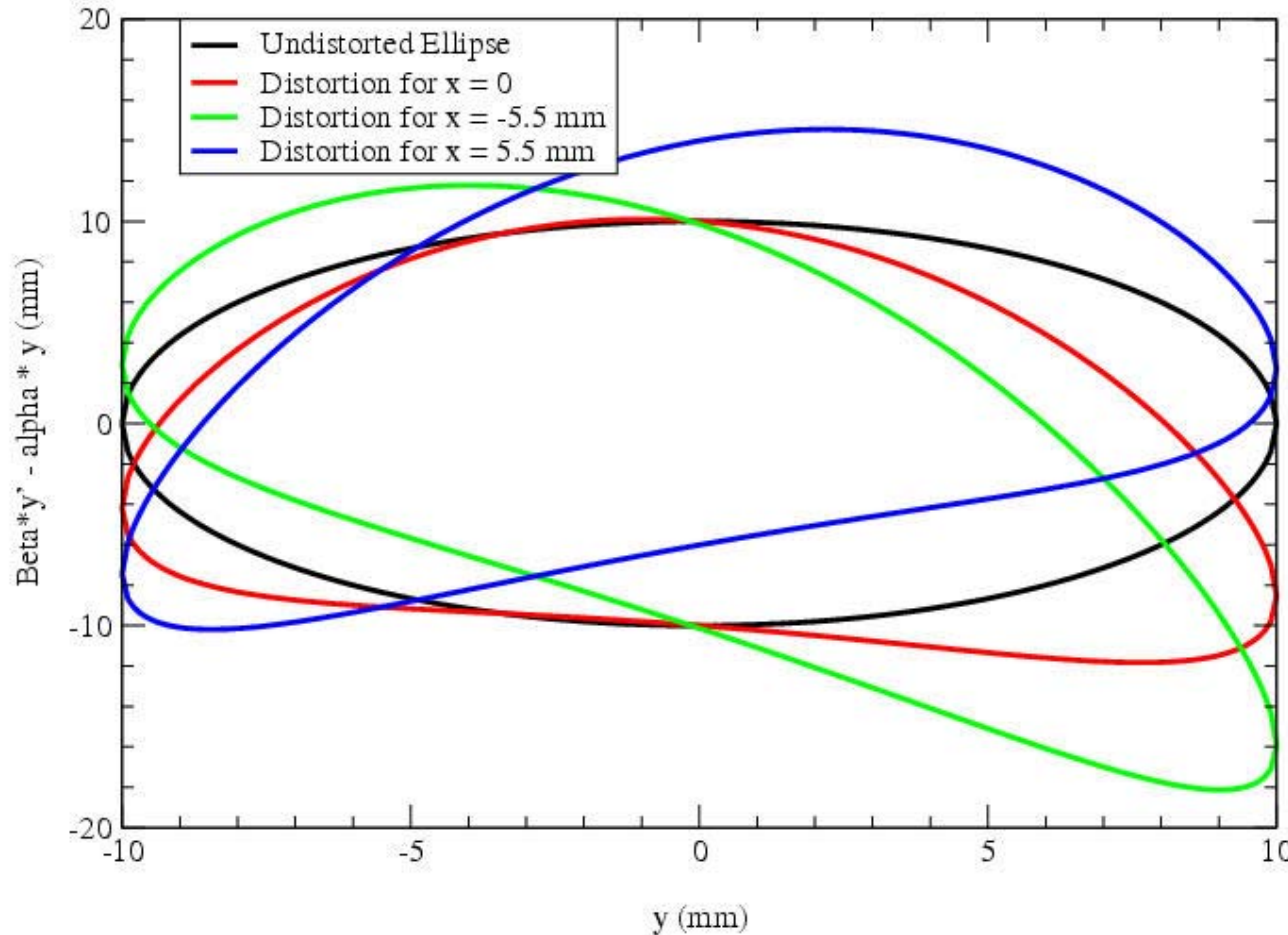
To remove $>0.1\%$ of Booster beam in transverse tails which would be lost in Main Injector. This should reduce somewhat the radiation levels in hot spots and the Main Injector and should greatly reduce the number of hot spot, permitting other radiation-inducing problems to be identified and controlled.

Specification:

Massive collimators designed for up to 2% of Booster beam lost without excessive residual radiation. Precision motion control outside of collimators.

Vertical Phase Ellipse after MP02 for 3.7 sigma particles

Distortion calculated for skew and normal Quad and Sextupole



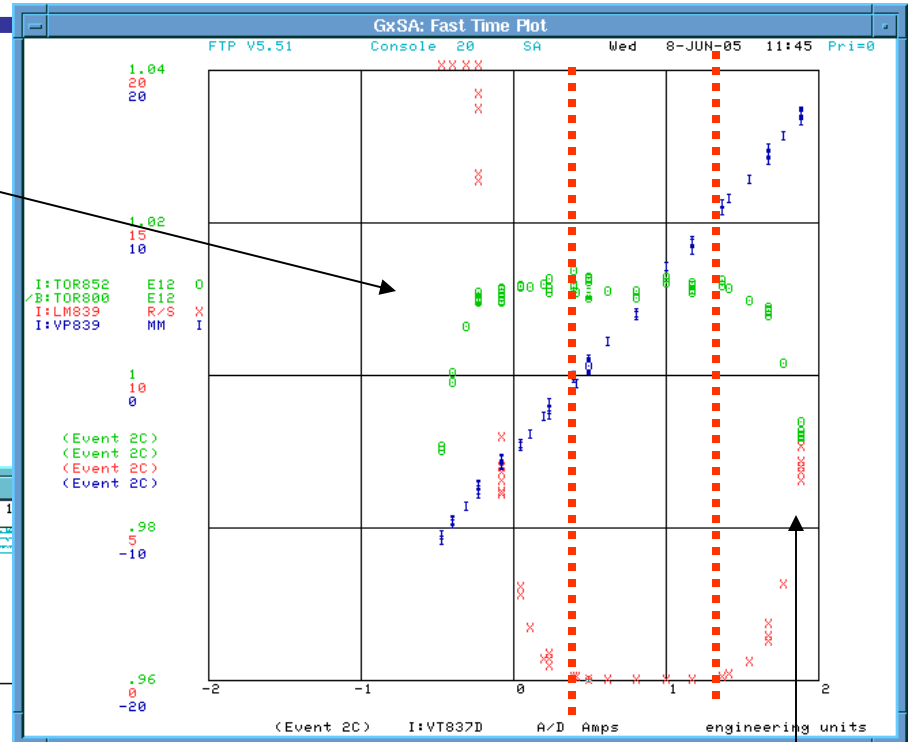
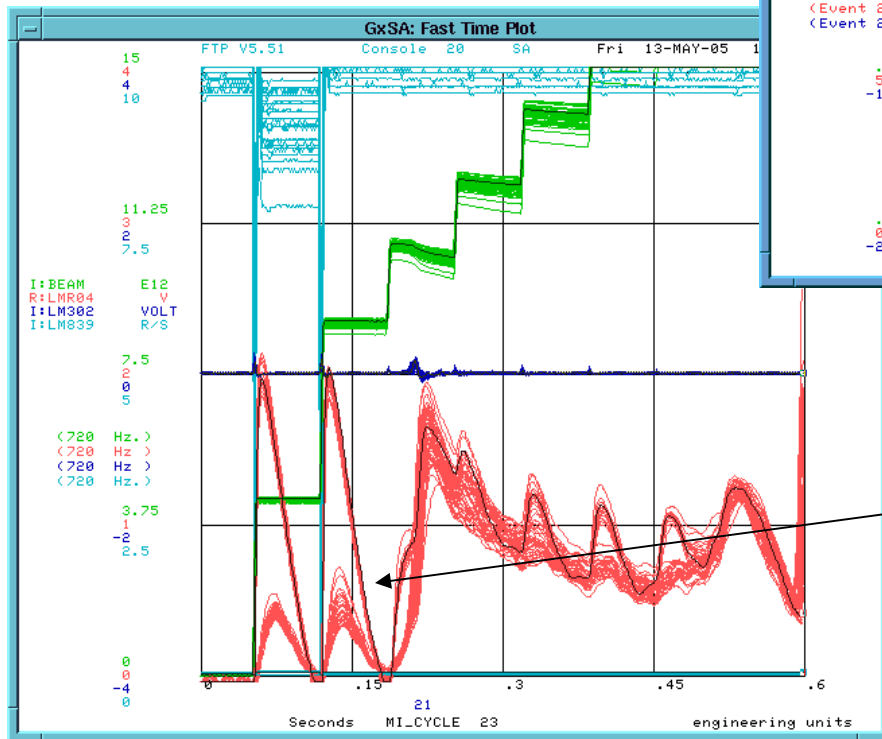
MP02 Harmonic
Errors from beam study
M-J Yang
Beams-doc-1573

Distortions
calculated for
three vertical
slices of extreme
Emittance beam
 $\pm 3.7\sigma$ vertically
slices at center
and $\pm 3.7\sigma$ radially

MP02 error from
Magnet measurement
somewhat smaller
Beams-doc-462

Asymmetric beam distribution at 839

Loss Monitor at ECool



Aperture scan at 839

Scraping level at 839 ~2%

Reduces losses at LMR04

Vertical phase advance from MP02 to 839 is $4.9 \times 2\pi$

In each region will insert:

- Vertical BPM
- 45" long collimator
- Bellows
- 45" long collimator
- Loss Monitor
- Fixed mask

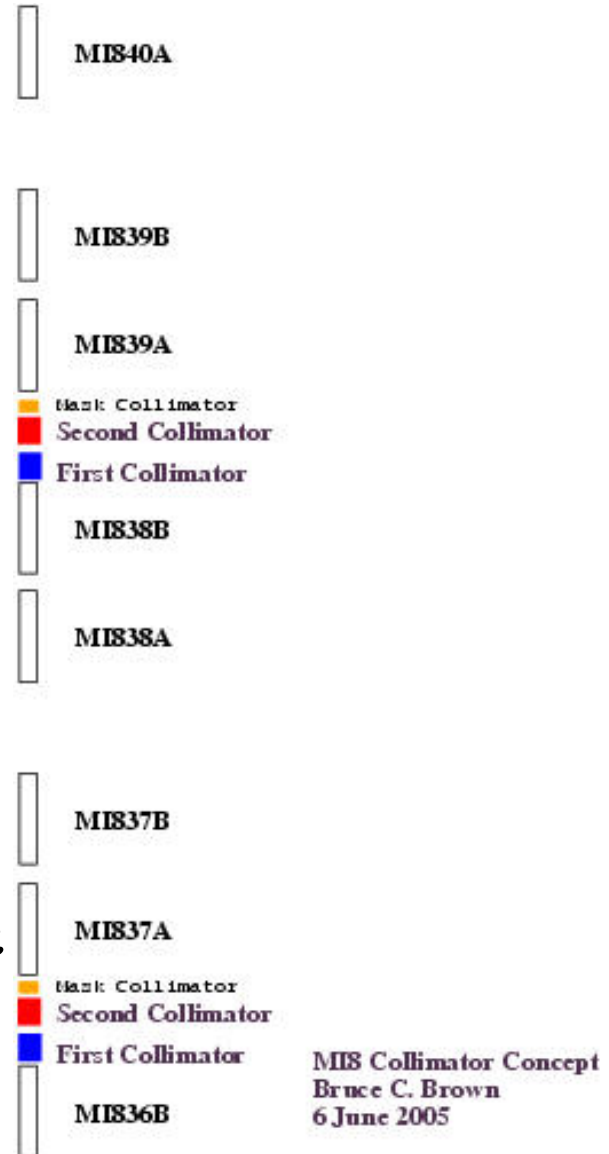
Each collimator has

2" x 2" vacuum hole

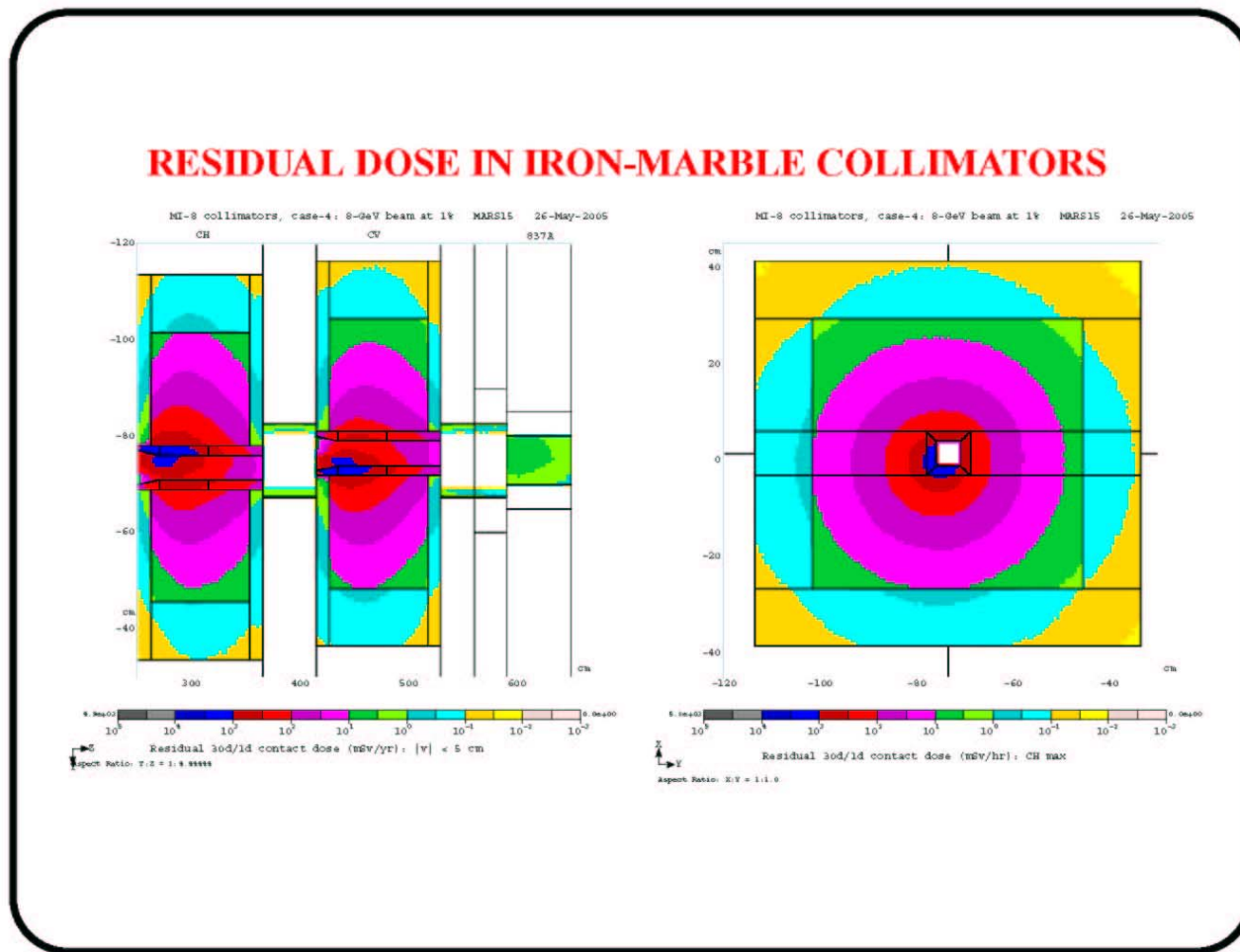
3.5" x 3.5" Stainless vacuum pipe

20" x 20" x 35" Steel absorber

30" x 30" x 45" Marble shield

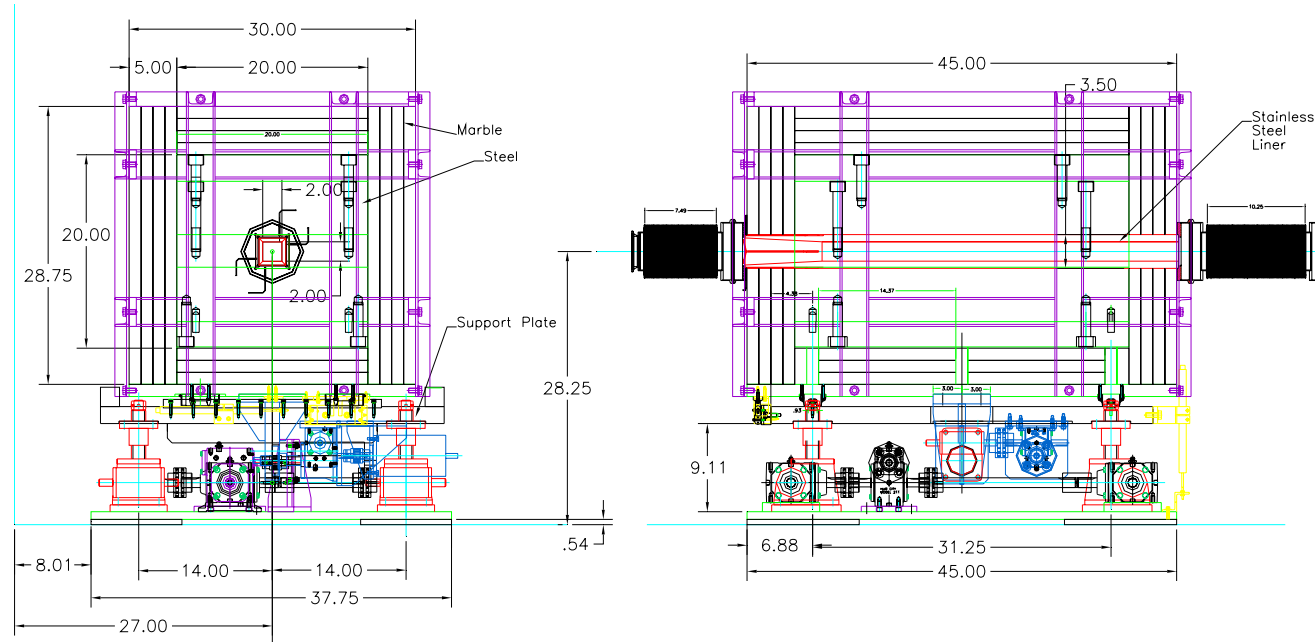


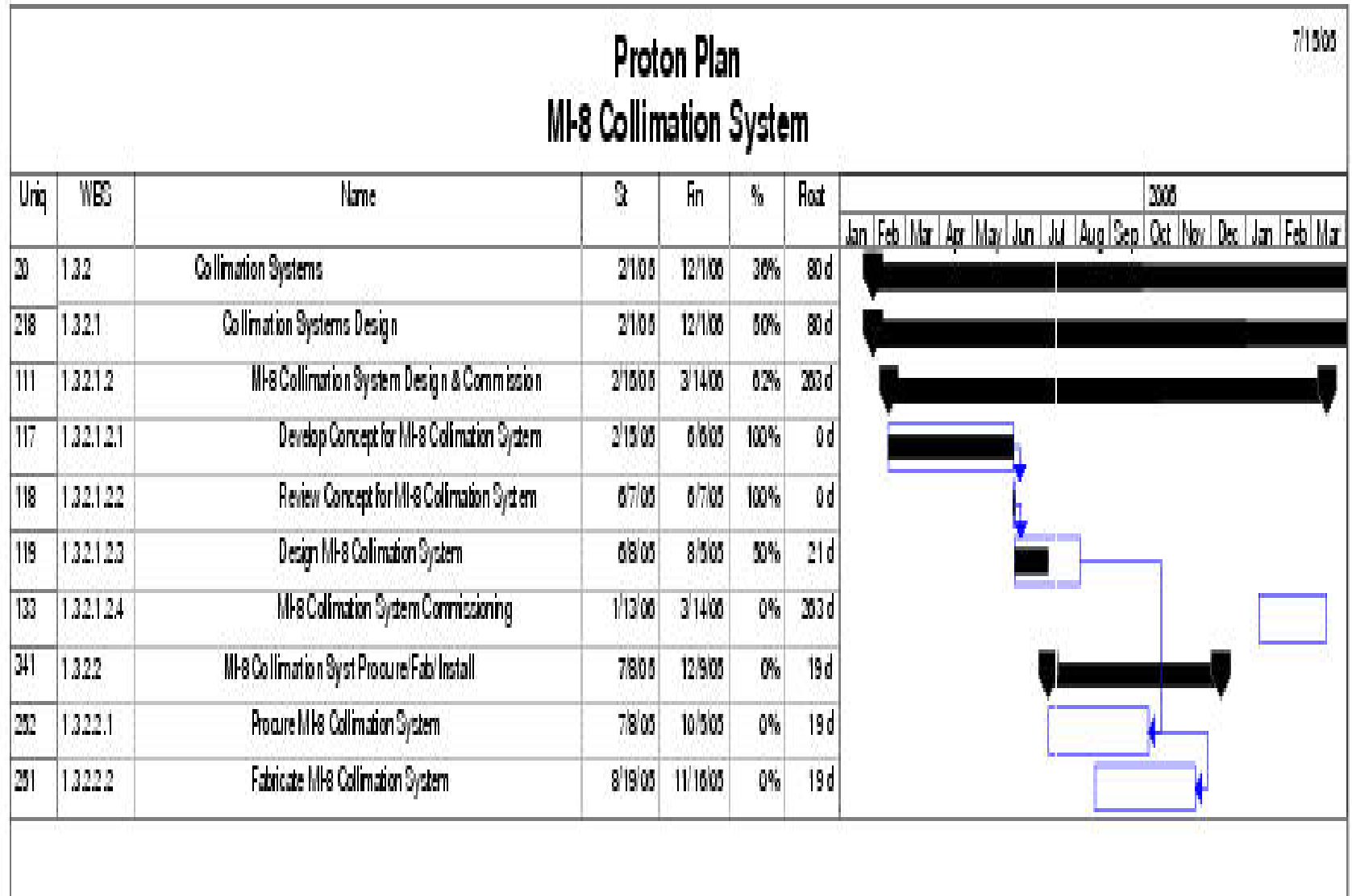
Design based on MARS calculations by N. Mokhov



Mechanical Design for One Collimator

- Motion control for horizontal and vertical motion





WBS	Name	Start	Finish	% C o m p l	Esc/Bur d La bo r	Esc M&S	Cont %
1.3.2	Collimation Systems (MI-8 Design & Fab Only)	2/1/05	12/1/06	36%	\$55,607	\$204,970	NA
1.3.2.1	Collimation Systems Design (MI-8 Only)	2/1/05	12/1/06	50%	\$35,114	\$0	NA
1.3.2.1.2	MI-8 Collimation System Design & Commission	2/15/05	3/14/06	62%	\$35,114	\$0	NA
1.3.2.1.2.1	Develop Concept for MI-8 Collimation System	2/15/05	6/6/05	100%	\$8,999	\$0	0%
1.3.2.1.2.2	Review Concept for MI-8 Collimation System	6/7/05	6/7/05	100%	\$0	\$0	0%
1.3.2.1.2.3	Design MI-8 Collimation System	6/8/05	8/5/05	50%	\$20,622	\$0	60%
1.3.2.1.2.4	MI-8 Collimation System Commissioning	1/13/06	3/14/06	0%	\$5,492	\$0	60%
1.3.2.2	MI-8 Collimation Syst Procure/Fab/Install	7/8/05	12/9/05	0%	\$20,493	\$204,970	NA
1.3.2.2.1	Procure MI-8 Collimation System	7/8/05	10/5/05	0%	\$1,673	\$204,970	60%
1.3.2.2.2	Fabricate MI-8 Collimation System (Future Parent)	8/19/05	11/16/05	0%	\$18,820	\$0	60%

Risk and Risk Mitigation Issues

Orbit Control not Adequate	Set for wider aperture (less collimation) until have auto tune or better power supplies
Schedule	Ordering long lead items now....
Assembly Manpower	Try to get design/fabrication in time to avoid manpower crunch.

Summary:

- Main Injector losses have grown - will continue to grow even with improved Booster Beam - we must control residual radiation produced by these losses.
- Plan is being implemented to provide bar-code labeled monitoring location and logging meter to allow monitoring of residual radiation with manageable personnel exposure.
- Improved loss monitor electronics available in 2006 will help maintain adequate knowledge of losses
- Program to measure, simulate and understand Main Injector losses is beginning soon. Expect to design MI collimator system despite serious lattice limitations.

Summary (continued):

Losses currently due to tails of injected Booster beam will create non-trivial residual radiation at proposed operating intensities.

Collimation in the MI8 Line to remove beam tails is specified and design/fabrication is underway.

Cost, schedule and manpower needs are manageable but will continue to require commitment to permit installation and commissioning in FY06.